under widely varying climatic conditions.[1] Observations were made at Puyallup, Wash.; Chico, Berkeley, Bard, Chula Vista, and Pasadena, Cal.; and Chillicothe, Tex. The authors summarize as follows:

(1) Sorghum is semitropical in its adaptations and does not thrive in regions of low temperatures.

(2) Sunshine is probably an important factor of growth, as evidenced by the difference of growth at Chula Vista, Calif., and Puyallup, Wash., where the mean temperatures and the total positive heat units available are but little different.

(3) The "physiological constant" for the ripening phase of sorghums according to Linsser's law of growth is about 0.53.

(4) Extremely high temperatures during the period of flowering and fruiting result in a decreased yield of seed.

(5) The date of planting should be so arranged that germination and early growth of the plants will take place during the period of high temperatures, and the flowering and fruiting when more moderate temperatures prevail.

(6) Adverse weather conditions affect such supposedly stable characters as the number of leaves per plant, as well as the volume of growth.

Linsser's law and its application to the matter in hand are given as follows:

"In two different localities the sums of positive daily temperatures for the same phase of vegetation is proportional to the annual sum total of all positive temperatures for the respective localities—that is, the heat required in any locality to produce a given phase of development in vegetation bears a constant ratio to the total positive heat units available in that place. This ratio has been styled the "physiological constant." If 50° (F.) is considered as the minimum temperature for growth in the sorghums, the yearly total of positive heat units at Chillicothe in 1915 was 5618° (F.); at Bard, 1915, 7989°; and at Chula Vista, 1916, 3600°. The positive heat unit required to bring the sorghums to maturity at Chillicothe were 3028° (F.), at Bard, 4236°, and at Chula Vista, 1,895°. It appears, therefore, that the physiological constant of sorghum for the period from planting to maturity is about 0.53. The conformance of the sorghums in these three cases to Linsser's law is rather remarkable, the exact ratio in each case being as follows:

Chillicothe	3,028; 5,618; or 0.539
Bard	4,236; 7,989; or 0.530
Chula Vista	1,895; 3,600; or 0.526

"Although Linsser's law seems to furnish a rule for the behavior of sorghums in respect to temperature, it does not take into account the effect of sunlight and other factors, which are also important."

Prof. Livingston has proposed a method by which both the moisture and temperature factors as affecting the growth of plants may be expressed as a single numerical value. The index thus proposed is the product of three factors—rainfall, evaporation, and temperature. (See Physiological Researches, vol. 1, No. 9, May, 1916, where the method employed is set forth in detail.) The indices proposed by this method are simply the product obtained by multiplying Transeau's rainfall-evaporation ratio [1] or the ratio of annual rainfall to annual evaporation for the period in question, by the summation index of temperature efficiency for the same period. He employs the physiological indices of temperature as derived from Lehenbauer's [2] results. This system, which takes into account the general principle of temperature minima, optima, and maxima, as related to plant growth, is described in Physiological Researches, volume 1, No. 8, pages 399–420, April, 1916.

A chart is presented in volume 1, No. 9 (ibid.), showing for the average frostless season a climatic zonation of the United States, based on the moisture-temperature indices as thus computed. The chart shows a very high potential climatic efficiency in the Gulf Coast region, where the supply of heat and moisture is great and the frostless season long, with rapid decrease northward and northwestward. The indices range numerically from 23,000 in central Florida to about 200 in portions of the central plateau districts of the West.

The high value of climatic efficiency obtained in the more southern localities by the Livingston method is due largely to the long frostless season in that area and the method used in combining the moisture and temperature factors. By taking the product of the two factors for a given period the resulting values increase rapidly with an increase of either factor and much more rapidly when both factors are raised. Thus, an increase of 100 per cent in one factor elevates the final result by a like amount, while an increase of 100 per cent in both factors results in an indicated climatic efficiency value fourfold greater.

[1] Ibid.

[1] Transeau, E. N., Forests of Eastern America. Amer. Nat. 39: 875–898, 1905.

[2] Lehenbauer, P. A., Growth of maize seedlings in relation to temperature, Phys. Res. 1: 247–288, 1914.

A GRAPHIC SUMMARY OF SEASONAL WORK ON FARM CROPS.

By O. E. BAKER, C. F. BROOKS, and R. G. HAINSWORTH.

[Separate 758, Yearbook, U. S. Dept. Agric., 1917 (pp. 537–589. 90 figs.). Abstracted and discussed.]

"This study contains maps showing the dates when planting, harvesting, and other operations are performed in the culture of the staple crops in different parts of the United States, and also graphs showing the seasonal distribution of labor by 10-day periods on typical farms in several important agricultural regions. Inscriptions under the maps afford information as to the hours of labor per acre required in growing the staple crops in various sections of the country."

Fifty-four maps show the usual dates when the most important operations are performed on winter wheat, spring wheat, winter oats, spring oats, corn, kafir corn, timothy, and clover, alfalfa, cotton, early potatoes, late potatoes (northern commercial crop), sugar beets, field beans, tobacco, Elberta peach, Ben Davis apple, strawberries, and tomatoes.

In preparing these maps, "the dates for each operation were entered from the schedules returned by the township reporters on large county outline maps of the States. The altitude reported on each schedule was indicated also. In making the general maps showing dates by isochronal lines, a strict use of the individual reports was not possible. This is because there is for many crop operations a wide range of dates in the reports received from a county. Such differences are due (1) to the physical conditions, such as temperature, slope, drainage, and soils on each farm; (2) to the individual practice of the farmer; and (3) to the difficulty of estimating for some crops and operations the dates in a normal or usual season as requested on the schedule. Therefore, where it was reasonable to do so, county averages of the reported dates were used. Such averages sufficed for most of the operations in flat regions, especially for such definite events as the beginning of wheat harvest. Three sets of conditions, however, prevented use of averages for all maps or for all parts of a map, namely, large differences in elevation; two or more periods of planting; and, for certain operations, an extended period during which the work can be carried on. Where the reports from different altitudes showed a well-marked topographic influence a contour map was used as an aid in drawing the isochronal lines. Where there were two or more well-defined planting periods the dates used were the modes or the averages of the most numerous group. Corn, spring oats, and late potatoes had to be treated in part in this way. Where the operation may be performed during an extended period the modal date was generally used, or the range in dates was shown on the map. In general, the maps show the average of the usual dates when most (not all) farmers perform the crop operation designated.

"The most striking feature of the maps is the northward and upward movement of spring operations and events and the southward and downward progress in autumn. This movement progresses at a rate of approximately one degree of latitude, or 400 feet of altitude, in four days. Local climatic influences of the Great Lakes and of the Atlantic Ocean are evident on almost every map. In operations which may be performed during a long period the maps indicate for the most part only the effect of local competition for labor by other crops, although the underlying control of general climatic conditions is not wholly obscured. Local markets may hasten the harvest of certain crops, such as potatoes, near the large cities."

The maps of the planting and digging of the northern commercial crop of potatoes, particularly the former (fig. 67, reproduced in fig. 1), show well the various factors involved in planting and harvest dates. Early potatoes are generally planted as early as possible, a certain amount of frost risk being taken[1] because of the value of early arrival of the crop on the market. The mean daily temperature at the time of planting is about 45° F.; thus, early potato planting occurs at about the time vegetative activity starts.[2] On this account the map "Early potatoes, date when planting begins" (fig. 63, reproduced in fig. 4, p. 315 above), shows perhaps better than a temperature map the progress of the season northward in the United States." In the case of the northern commercial crop of potatoes, the planting time is of little consequence. In the southern part of the corn belt there is ample time for potato planting before the mean temperature rises high enough (about 55° F.)[3] for corn planting. In the northern portion of the corn belt, on the contrary, the planting of the large oats crop occupies most of the time between the advent of planting weather and the time when corn can be put in. Thus, while most of the farmers in southern Indiana plant their "late" potatoes in the middle of April, before corn planting, the majority of those in northern Indiana are not putting in their late potatoes until the end of May or early June, after corn planting. "In the Maine, New York, Michigan, Wisconsin, and Minnesota districts [the planting dates are generally earlier, for] the necessity

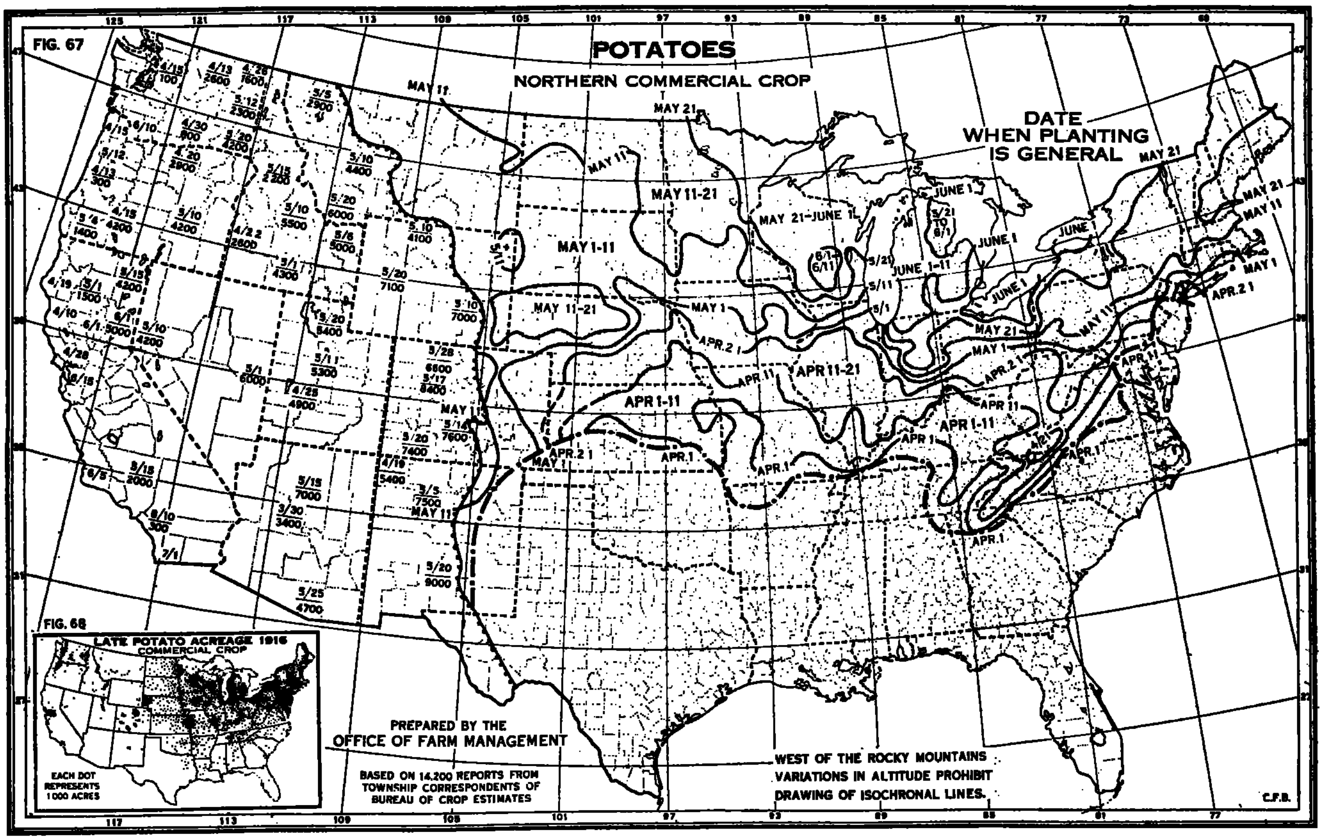


FIG. 1.

[1] Cf. Reed, W. G., and Tolley, H. R., "Weather as a business risk in farming," *Geogr. Rev.* 1916, vol. 2, pp. 48-53.

[2] Cf. Kincer, J. B., "Relation between vegetative and frostless periods," Monthly Weather Review, 1919, 47:106-110; and "Temperature influence on planting and harvest dates," pp. 312-313, above.

[3] See pp. 315-317, above.

of digging the crop before the ground freezes limits to a period of a few weeks not only the digging but also the planting of potatoes. Owing to the moderate autumn temperatures along the Lake shores in Michigan, [Ohio], and New York, however, digging may be delayed as late as the latter half of October." This seems to explain why general planting is delayed till early June in such favored localities.

Comparisons of other groups of maps bring out many reasons for the peculiar distribution of dates when various crop operations are performed. In general, the seasonal control is most evident on the maps of the following operations: Beginning of planting of spring wheat, spring oats (fig. 2, p. 314, above), early potatoes (fig. 4, p. 315 above), corn (fig. 6, p. 316, above), and cotton (fig. 8, p. 318, above); and beginning of harvest of wheat (fig. 2), oats (fig. 3), potatoes, cotton, and Elberta peaches.

caught up with the winter wheat. In the week ending June 19 both harvests had advanced north to Kansas and Missouri; in the last week of June winter wheat harvest had advanced to southeastern Virginia, and oats harvest to southeastern north Carolina. A marked delay of two weeks in the Great Plains and of four or five weeks in the East brings attention to the cool, wet spring which delayed planting, and to the cool weather which retarded the development of the grain. As the winter wheat harvest dates, obviously, were not affected by any lateness of spring planting, the harvest advanced northward at the usual rate, although 10 days or more late. * * *

"The warm, dry weather, beginning early in July, on the Great Plains so accelerated the harvests that winter wheat finished only a week late, and spring oats on the usual dates. East of the Mississippi, however, the hot week of July 24 marked the first rapid advance of the

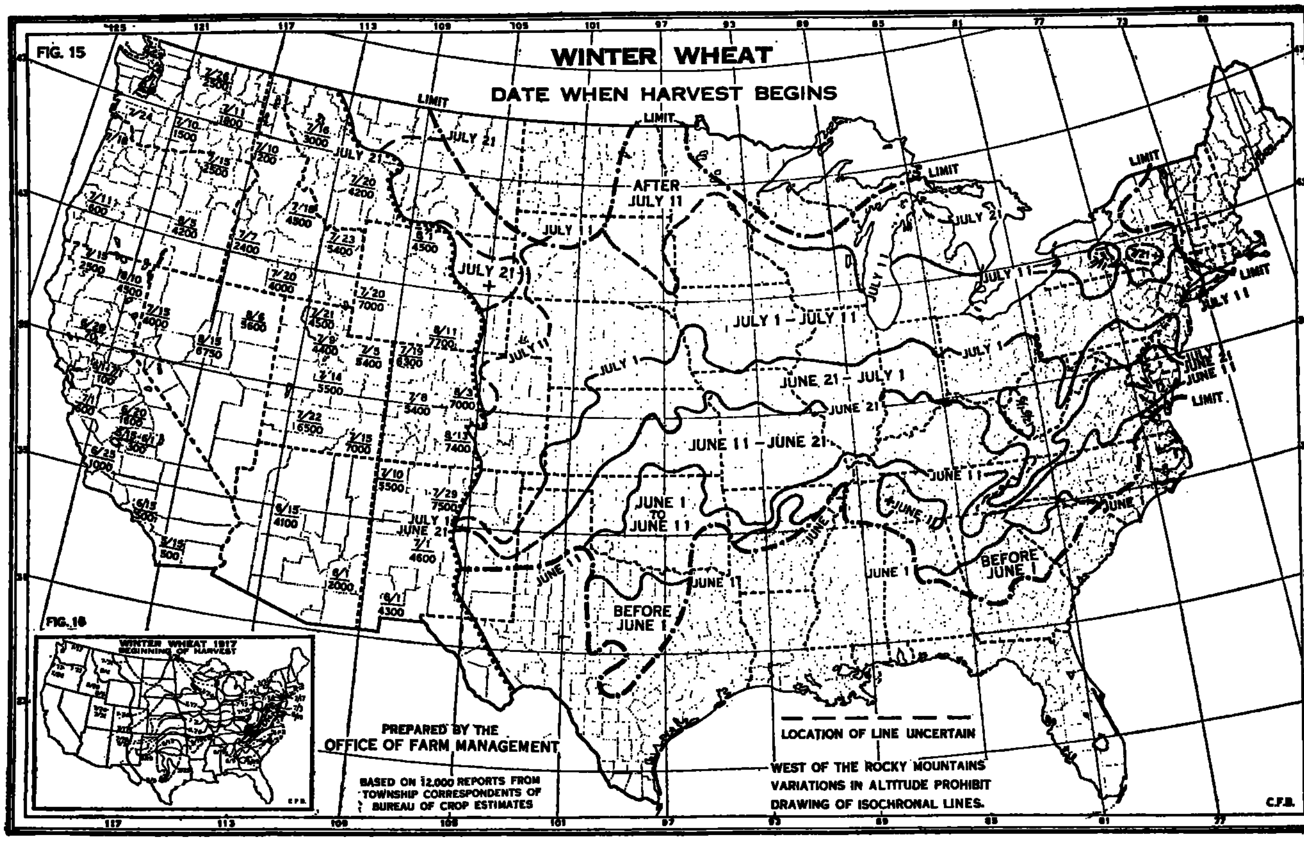


FIG. 2.

There are three maps showing the actual progress of the beginning of harvest of winter wheat, spring wheat, and spring oats in 1917, when the line of the harvest front was mapped from telegraphic data each week for farm labor distributors.[4] These maps were discussed in the National Weather and Crop Bulletin, August 28, 1917, pages 2 and 3, from which the following quotations are taken:

"Before the end of May the harvest of winter wheat (fig. 16, in fig. 3) was in progress from southern South Carolina to central Alabama and in central Texas; the spring oats harvest (fig. 36, reproduced in fig. 3) was following about a week later. Warm, wet weather, followed, in the South, by a cool, dry week during the first half of June, brought the oats harvest northward so rapidly that it almost

harvest. In the cool preceding fortnight the winter wheat harvest had advanced from the southwestern to the northwestern corner of Ohio. The hot week brought the spring oats harvest front over the same distances in half the time, so that the spring oats harvest was only 10 days late in the same place where a week earlier the winter wheat harvest had been 21 days late * * *."

One map (fig. 13 reproduced in fig. 4) shows the "date for seeding [winter wheat] which will, in the normal year, reduce or avoid injury by the Hessian fly and probably give a greater yield." The original background of this map is fully discussed by Dr. A. D. Hopkins in his monograph, "Periodical events and natural law as guides to agricultural research and practice" (MONTHLY WEATHER REVIEW, Suppl. 9, 1918, 4 to 40 pp., 24 figs.; see also Scientific Monthly, June, 1919, pp. 496–513). The lines on the fair climatic map showing the beginning of winter wheat

[4] Similar maps were published in the National Weather and Crop Bulletin weekly during the summer of 1918.

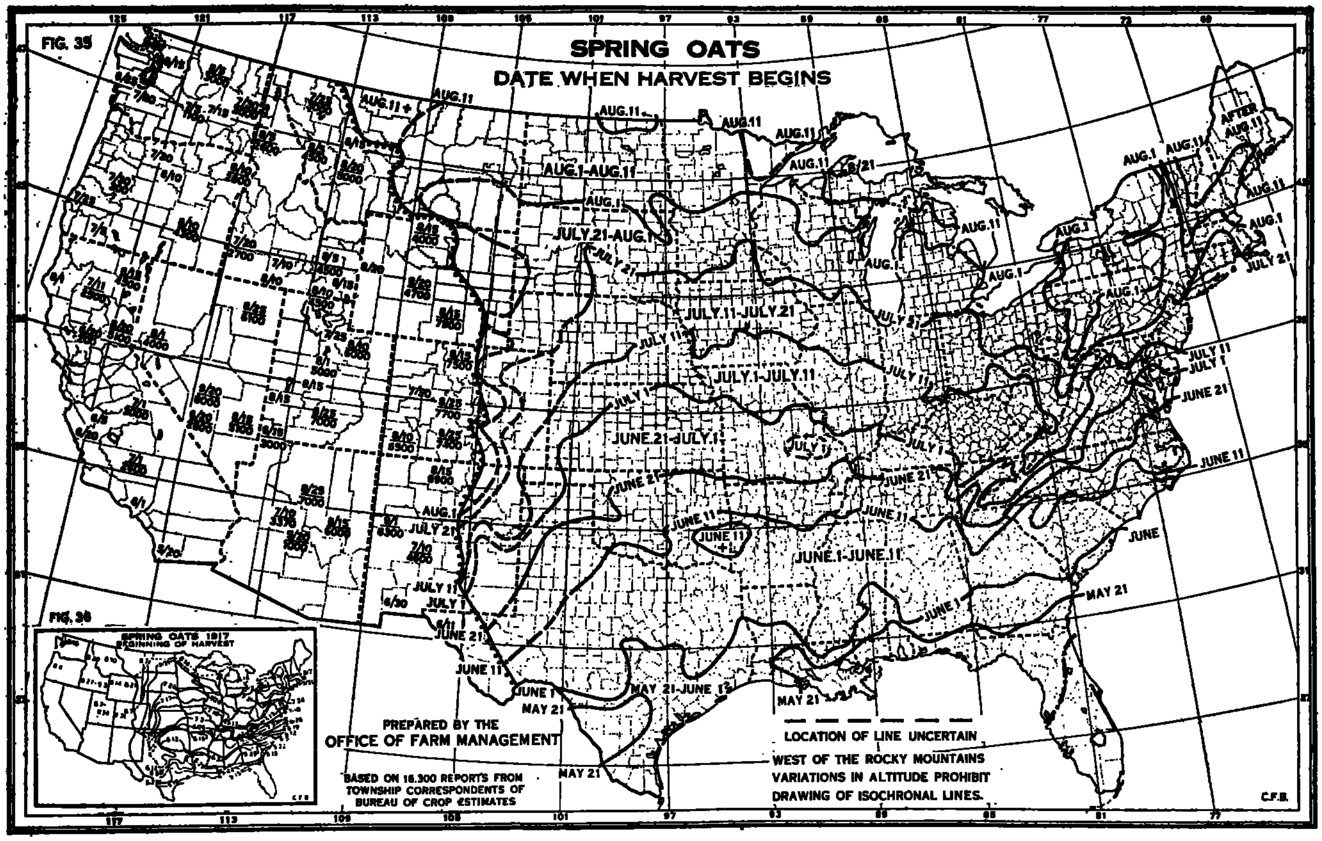
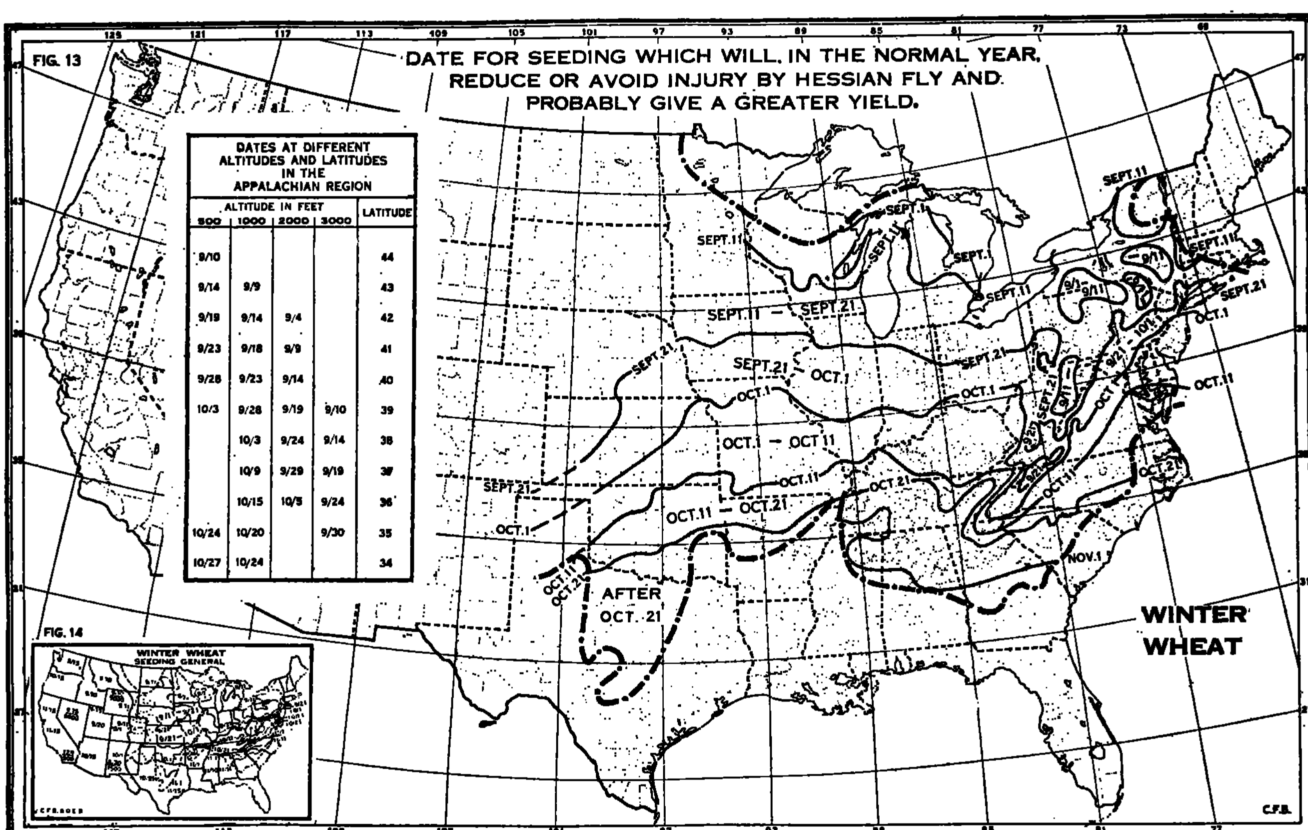


FIG. 3.



DATES AT DIFFERENT ALTITUDES AND LATITUDES IN THE APPALACHIAN REGION

ALTITUDE IN FEET 500	1000	2000	3000	LATITUDE
9/10				44
9/14	9/9			43
9/19	9/14	9/4		42
9/23	9/18	9/9		41
9/28	9/23	9/14		40
10/3	9/28	9/19	9/10	39
	10/3	9/24	9/14	38
	10/9	9/29	9/19	37
	10/15	10/5	9/24	36
10/24	10/20		9/30	35
10/27	10/24			34

FIG. 4.

harvest (fig. 15, reproduced in fig. 2) were used with a new set of dates to make a map of the advance of autumn. Local modifications were necessary to allow for the effects of the Great Lakes and Atlantic Ocean. Such a map may be used as a general basis for "safe" wheat seeding, because the development of the Hessian fly is closely dependent on late-summer and autumn weather.

The lines were dated and modified in "an attempt to correlate the recommendations of the different experiment stations as to the date of seeding winter wheat. The results of experiments in Kansas, Nebraska, Iowa, Indiana, and Ohio show that when the Hessian fly is prevalent the best yields may be expected when the seeding occurs just after the emergence of the last autumn brood of the fly; and when the fly is not numerous, the best time for seeding generally is about a week earlier. In the years when the fly is prevalent the actual dates to be recommended depend on experiments in the fields at the time, so in such years it is necessary to follow closely the recommendations of the State entomologists. Planting in the North depends largely on the season and the labor situation. South of the thirty-ninth parallel and east of southeastern Kansas the autumn is long enough to allow seeding after the average date of emergence of the fly, with the best chance of still securing the maximum yield." The altitude-latitude table inserted in the map represents the reverse of the latitude and altitude rate of progress of winter-wheat harvest, which progresses about a degree of latitude or 400 feet of general altitude in 4 days.

As Dr. Hopkins points out, there are many other ways in which the maps showing the actual dates of operations can be used as a basis for improving farm practice and for determining the best regions for expanding the average of different crops.

Supplementing these isochronal maps, are 17 "dot" maps showing the acreage distribution of the crops mentioned. Two maps show the regions where corn is cut and shocked, and where corn is jerked from standing stalks. Two graphs show the production of early and of late potatoes by date of harvest zones. The applications to farm management and farm labor problems are brought out in detail by graphs showing the hours devoted to different farm operations by 10-day periods throughout the year at seven typical farming regions of the United States. There are three large dot maps showing the distribution of farmers, of farm laborers, and of expenditure for labor.—*C. F. Brooks.*

DUFRÊNOY'S OBSERVATIONS OF THE TEMPERATURES OF PLANTS IN SUNLIGHT AND SHADE.

The difference in the temperature of plants in direct sunshine and in shade, and the action of the pigments in varying the temperature of different colored leaves and plants in sunshine, is shown in a recent article by the French naturalist Mr. J. Dufrénoy, of the biological station at Arachon, in the Revue Générale de Sciences.

He explains the formation of the pigments in plants, and the increase or decrease of pigmentation with varying heat, moisture, and sunshine values, then shows the effect of these different pigments in the absorption of solar energy.

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We quote the following from a recent review of this article in the Scientific American Supplement for February 15, 1919:

* * * The solar energy absorbed by the pigments is largely converted into heat. In January at Arachon, on a fine day, the temperature of the plants exposed to the sun exceeds that of the air by from 6° to 8° C. at noon, and by from 12° to 15° C. at 3 p. m.; the amount of this rise in temperature varies according to the color and to the intensity of the pigmentation, so that a difference of more than 1° C. may exist between the yellow and the green leaves of the variegated foliage of a spindle tree, or even between the two borders of a single variegated leaf.

Experiments made in January at Arachon gave the following results: In a variegated leaf of the *Iris pallida* the green portion showed a rise in temperature of 9.8° C. over that of the air against a rise of only 8.5° C. in the yellow portion. Similar observations were made with the red and green leaves of an arbutus, the time being 10 a. m. and the temperature of the air 10° C.; in this case the red leaf showed a rise of 7.5° C. and the green leaf a rise of only 7° C.

* * * * *

In November tests were made at 2 p. m. with red and white arbutus berries, the temperature of the latter being 29.5° C. and that of the red one degree higher.

Finally experiments were made with grapes of various colors placed in sunshine and in shade. The temperature of the red grapes in the sun was 37° C. and 10° C. less in the shade; that of white, green, and amber colored grapes was 34° C. in the sun, and 26° C. in the shade. The time of this last experiment was October 10, at 3 p. m., the temperature of the air being 24° C. in the shade. A second experiment showed that grapes with a dull surface had a temperature of 35.5° C. in the sun, whereas that of those with a bright surface was 34.8° C.

A highly interesting fact is that every rise of 10° C. in the temperature of the organs exposed to sunlight doubles or even trebles the rapidity of the reactions observed—for example, the intensity of respiration is greatly enhanced, more carbon dioxide being liberated.

In fruits exposed to sunlight the plant acids contained are reduced, and the ripening is correspondingly hastened. * * *

These experiments illustrate the difficulty in making comparable records of the temperature of plants in sunshine as made by different investigators, or by the same man at different times.—*J. Warren Smith.*

NOTE ON THE HEATING OF PLANTS IN SUNLIGHT AS A FACTOR IN GROWTH.*

By D. A. SEELEY, Meteorologist.

[Dated: Weather Bureau, Lansing, Mich., May, 1919.]

The results of M. Dufrénoy's observations on the temperature of plants, as quoted above, offer further evidence of the importance of sunshine in plant growth. Differences of 12° to 15° C. (22° to 27° F.), noted by M. Dufrénoy between leaf and air temperature on clear days, are not in excess of those observed by several other investigators at various times. Such large temperature differences must surely produce marked metabolic activities in the plant, not to mention the actinic influences. The fact that under sunshine plants are so much warmer than the air should be given more consideration in studies of the relationship between weather conditions and plant growth. In the past it has been the custom to study air temperature in relation to plant growth without considering the often widely different temperature of the plant itself, especially in sunshine. The "Summation method," by which the excess of air temperature above a given limit is computed, gives widely divergent results when worked out for a given life phase of plants in different years, largely on account of the failure to take into consideration the difference between plant and air temperature. When the sun is shining the air temperature does not register the true thermal con-

* Cf. "Crops and temperature," Abs. in Mo. WEA. REV. 1917, 45: 354-359.